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AD-E402 802

Technical Report ARWEC-TR-97002

## **REPLACEMENT OF FIRST FIRE COMPOSITION IN M127A1 GROUND ILLUMINATION SIGNAL**

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December 1997



### **U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER**

Warheads, Energetics & Combat-support Armaments Center

**Picatinny Arsenal, New Jersey**

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## REPORT DOCUMENT PAGE

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE December 1997	3. REPORT TYPE AND DATES COVERED	
4. TITLE AND SUBTITLE <b>REPLACEMENT OF FIRST FIRE COMPOSITION IN M127A1 GROUND ILLUMINATION SIGNAL</b>		5. FUNDING NUMBERS -	
6. AUTHORS Russell N. Broad			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  ARDEC, WECAC Energetics & Warheads Division (AMSTA-AR-WEE-F) Picatinny Arsenal, NJ 07806-5000		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)  ARDEC, WECAC Information Research Center (AMSTA-AR-WEL-T) Picatinny Arsenal, NJ 07806-5000		10. SPONSORING/MONITORING AGENCY REPORT NUMBER  Technical Report ARWEC-TR-97002	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT  Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  A study was conducted to replace the first fire composition in the M127A1 ground illumination signal. The original first fire composition contained tetranitrocarbazole, a sole source material, and barium nitrate, a toxic material. Program costs were minimized by choosing a presently used first fire composition as a replacement. A data base of such compositions was created. It was used to pick candidate replacement compositions. The compositions were loaded into illuminant assemblies and tested statistically. Results from this test showed that Starter Mix (SM) XXV was the best candidate composition. It was loaded into complete signals that underwent ballistic testing. Signals with SM-XXV met all applicable Military specification requirements. The success of the program justified the approach of choosing a currently used first fire composition.			
14. SUBJECT TERMS First fire      Igniter      Tetranitrocarbazole      Colored signal Illuminating      Candlepower      Illuminant			15. NUMBER OF PAGES <b>22</b>
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT <b>UNCLASSIFIED</b>	18. SECURITY CLASSIFICATION OF THIS PAGE <b>UNCLASSIFIED</b>	19. SECURITY CLASSIFICATION OF ABSTRACT <b>UNCLASSIFIED</b>	20. LIMITATION OF ABSTRACT <b>SAR</b>

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)  
Prescribed by ANSI Std Z39.18  
298-02

DTIC QUALITY INSPECTED 3

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## INTRODUCTION

The pyrotechnic first fire compositions covered by MIL-P-48240 are used on a wide range of colored signals and illuminating projectiles. There are three of these compositions, each formulated to give a distinctive color. Table 1 give the formulations for these compositions. TNC is a common constituent of these compositions. TNC was first synthesized in the late 1800s and found use in pyrotechnics in World War II (ref 1). Picatinny Arsenal investigated its use as a first fire constituent in the early 1950s (ref 2). It is considered an explosive material. Upon ignition it produces considerable energy and essentially gaseous products. These properties enable the first fire compositions to ignite illuminating and signal compositions. The first fire compositions are either pressed on top of, or brushed onto, the surfaces of illuminating and signal compositions pressed into canisters or sleeves. The first fire compositions are initiated by expelling charges or ignition compositions. Through the years, the first fire compositions have given reliable, consistent performance.

In the early 1990s, the availability of TNC became uncertain because its sole producer did not want to manufacture it anymore. Although another company picked up production, availability could not be guaranteed. TNC has no commercial market and the military market has declined dramatically. The resulting low demand make its production marginally profitable. Thus, there is little motivation to continue its production. This situation led to execution of an engineering study to eliminate use of TNC. A secondary purpose of the engineering study was the replacement of barium nitrate in the igniter compositions. This material is in two of the pyrotechnic first fire compositions. Like all water soluble barium salts, it has high acute toxicity. Further, disposal of waste containing it is relatively expensive because it cannot be landfilled. This report describes the results of the engineering study.

## TECHNICAL APPROACH

One approach to remove TNC could have been reformulating the first fire compositions without it. This would have resulted in novel compositions. The approach taken, however, was replacement of the three first fire compositions with a pyrotechnic composition that was presently being used on other items. The advantages of this approach follow. First, it minimized testing required for qualification since a presently used composition had a history associated with it. This included functioning performance in various end items, environmental considerations, cost and data on storage stability, safety, thermodynamics, and kinetics. Second, manufacturing procedures and drawings already existed for the composition. Third, use of one first fire composition would simplify manufacturing since one batch of composition could be used for various items, regardless of the items' signal or illumination colors.

One possible drawback to this approach was the elimination of first fire compositions that were tailored to the illuminating or signal composition color. Several individuals knowledgeable in the field use the colored signals revealed that the color of the first fire flash was insignificant in affecting an observer's ability to distinguish illuminant or signal colors. The flash of the first fire is of very quick duration (<500 ms) compared to the burn time of the illuminants or signals (>25 sec). Thus, elimination of the color requirement for the first fire compositions was of no concern and this approach was pursued.

The program was conducted in three phases. First, other presently used pyrotechnic compositions were identified and pertinent data was collected on them. For maximum flexibility, we did not confine our search to only igniter and first fire compositions (henceforth we will use the term first fire to apply to igniter compositions as well). A data base was created from which the best candidate compositions were selected. Second, static functioning tests were performed on illuminant assemblies which contained the candidate first fire compositions and the standard first fire compositions. These tests determined if the candidate replacement compositions would have any adverse affect on the static requirements for the illuminating assemblies. Third, items were loaded with both the candidate replacement composition and the standard first fire composition, and underwent first article ballistic testing.

## RESULT

### **Composition Data Base/Selection of Candidate Compositions**

Identification of presently used first fire compositions was begun by generating a list of drawings that contained words igniter, ignition, and first fire in their titles. These drawings were then obtained. A second source for such compositions was reference 3. This procedure ensured that the vast majority of, if not all, presently used first fire compositions were identified. With this information, a minimal data base that included first fire formulations and common names was created. Further information was then added. This included impact, electrostatic and friction sensitivity data, hazard class, heat of reaction, autoignition temperature, burn rate, cost per pound, and qualitative ranking of toxicity. Not all of this data could be obtained for every composition. The data base is shown in table 2. The references for the various data are cited in the table.

Criteria were developed to select the most promising candidate replacement compositions. Criteria included toxicity, cost, sensitivity, availability of constituents, history of problems, and burning characteristics. It was decided to eliminate those that would be least likely selected. The first criterion for elimination was presence of acutely toxic or carcinogenic constituents. This included barium, lead salts, and chromates. This consideration eliminated many of the compositions shown in table 2 as candidates. The remaining compositions were eliminated because of safety or processing issues, autoignition temperatures exceeding 500°C (ref 4), or other considerations such as cost. Since the first fire compositions are in contact with the flash from expelling charges for short duration's, they must reach their autoignition temperatures quickly. This is more easily accomplished if the autoignition temperature is relatively low. The remaining compositions, which were chosen as candidates, were Starter Mix XXV, IM-6, and I-548 (no. 10, 34, and 40, respectively in table 2). Table 3 shows further detail on these compositions.

### **Static Tests of Candidate Compositions**

Composition I-548 was dropped from consideration because the required grade of calcium resonate could not be obtained easily. Only starter Mix XXV and IM-6 were evaluated statically. Table 4 is a matrix of assembly types and quantities statically tested. Assemblies with the standard first fire compositions served as controls. The choice of assemblies was based upon the items planned for the qualification tests. In turn, the choice of items was based upon what items would be in production during the duration of the program.

The required parts for the assemblies were ordered and tooling was fabricated for loading the assemblies. The Pyro Systems Branch of the U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey mixed all the pyrotechnic compositions and loaded all the assemblies used in the static tests. The Branch also conducted all the static tests in its own flare tunnel. Table 5 is a roll up of averaged static test parameters for the assembly/first fire combinations tested.

The efficiency data shows that SM-XXV offers significantly better performance over IM-6 for the M125A1 and M127A1, while the IM-6 is much better for the M158. They are nearly equal for the M583A1. SM-XXV was better than the standard first fire for all items except the M583A1. Here, the standard was approximately 13% higher. Based on this static data, as well as SM-XXV's lower cost, we decided to test SM-XXV in the ballistic testing.

#### **Ballistic Testing for Prove Out of New First Fire Composition**

In consultation with ARDEC's Product Assurance and Test Directorate, a test plan was drafted for ballistic testing. The ballistic test consisted of functioning tests at conditioning temperatures specified in the military specifications. Additionally, some illuminant assemblies from the lot used for the ballistic test were statically tested. Quantities were per first article requirements. This minimal amount of testing was justified since changing the first fire would in no way affect the hardware and other energetic material fills in the item.

The ballistic tests were conducted by Thiokol Corporation at Longhorn Army Ammunition Plant (LHAAP). During the time period in which static testing at ARDEC concluded and ballistic tests began, numerous production lines were closed at LHAAP. Startup of these lines exclusively for this program would have been prohibitively expensive. Consequently, only the M127A1 signal experienced ballistic testing.

Thiokol loaded the items per the technical data package requirements and performed testing per the Scope of Work. Table 6 shows their static burn data. The candlepowers measured at LHAAP were higher than ours; this was due to differences in the tunnels and test procedures. As expected, the candlepower achieved with SM-XXV was higher than FF-I. Since exact illuminant weight data was unavailable, efficiencies are not reported. Table 7 presents the ballistic (flight) data. The data shows that aside from two failures at 70°F, all signals met the requirements. One failure was non-expulsion of the signal; the other, failure of the round to expel. Neither was related to first fire function. The only ballistic parameter that could have been possibly affected by the change in first fire was the burn time. The differences between the signals with FF-I and SM-XXV for this parameter were small and within the standard deviations at all temperatures.

#### **CONCLUSIONS**

The success of the project vindicated the selected approach. Choosing a presently used igniter composition kept the cost and technical risks of the program as low as expected. The need for extensive testing above first article requirements was eliminated.

## RECOMMENDATIONS

Other items incorporating igniter compositions with sole source, toxic, or environmental/objectionable constituents should be evaluated for igniter replacement. Programs to achieve this objective would be of minimal scope since they would have the data base of igniters generated in this program as a starting point.

Table 1  
Formulations for pyrotechnic first fire compositions

<u>Constituent</u>	<u>Requirements</u>	<u>Nominal weight percent</u>		
		Type I	Type II	Type III
Barium nitrate	MIL-B-162 Average particle size $\leq 20 \mu$	50	---	50
Strontium nitrate	MIL-S-20322 Grade A or B	---	50	--
Tetranitrocarbazole	MIL-T-13723	10	10	10
Silicon	MIL-S-230 Average particle size $\leq 10 \mu$	20	16	13
Zirconium hydride	Commercial	15	15	20
Polyvinyl chloride	MIL-P-20307	---	5	3
Laminac 4116 + 1% Lupersol DDM catalyst	Commercial	5	4	4
Color requirement		Yellow	Red	Green

**Table 2**  
**Database for first fire and pyrotechnic compositions**

**Table 2 Database for first fire and pyrotechnic compositions**

No	Fuel (Percent)	Oxidant (Percent)	Additive (Percent)	Blinder	Solvent	Type	Cost	E-Sta. (J)	Fric.P	Impact	BR	Heat	1g. Temp	Compat	Toxicity
1	Lead Azide														
2	2 Nitrocellulose													D /1.1	Not Toxic
3	PETN													/1.1	
4	TNT													/1.1	
5	RDX													/1.1	
6	Black Powder														
7	98.5-99 RDX														
8	30 Charcoal	70	KNO3												
9	83.3 Dry Mix Dry Mix (#1), 26/4/13 Si/C/Al Bindersoln(#9);	35/22 KN03/Fe203			6 NC	94Acetone		0.59	145					D /1.1	Slight
10	26/13/4 Si/Al/C	35/22 KN03/Fe203												/1.3	SLIGHT
11	60 Dry Mix Dry Mix (#1), 16-8/10 Si/C/Starch	43.2/30 BaCO3/NaHCO3 Bindersoln(#1);			40 B. Solu.										
12	35 pts Sb	35/30 pts CaSi2/KCl04			66p ts (B NC 92 Ace.)										
13	40 Al	30/30 Ba(NO3)2/KCl04													
14	23/15 Al / S	62 Ba(NO3)2													
15	9 Bl. Powder	9 Al													
16	34/26 Mg/Al	40 KCl04													
17	25.5/12.8 Mg/Al	25.5/28.1 BaCO3/KCl			8.1Uton A	B. Acetate FF		22.4	0.0125	CD/CD	6			A /1.1	TOXIC
18	50/50 FF/F1are FF, 10 B Flare: 65 Mg	20 BaCO3 28 Teflon													
19	Dry Mix & B. Solu. Dry Mix (#16), 25/25 Ti/Si Bindersoln	25/25 Fe3O4/Pb3O4			(10.9 NC	89.1 Acetone)									
20	30 w	55.10 BaCrO4/KCl04	5 D.earth	Viton A											
21	25/25 Si/Ti	50 Pb3O4	(Graphite	NC	Acetone	FF Mix X		1.625	NR 215	0.35/mg	275	780	6 /1.1	MOD	
22	10 B	70 Pb02													

Table 2  
(cont)

Table 2 Database for first fire and pyrotechnic compositions

No	Fuel	Oxidant	Additive	Blinder	Solvent	Type	Cost	E-Sta.(J)	Fric.P	Impact	BR	Heat	Ig.Temp	Compat	Toxicity
(Percent):	(Percent):	(Percent):	(Percent):	(Percent):	(Percent):	of Comp.	\$/lb	Uncon/Con	Steel/F	PA,(")	**As	offRec	Degrees C	Gr/Haz	*****Ref
						of Comp.					Shoun	Cal/g	Auto/DTA	(DDO)	
23	33 BK Powder Red Pyro Comp. 1 2/171 Mg, Granil Mg, Gran 4	67 Red Pyro. Comp. 13/21.4 NaNO3/KC1041 2.8 Graphite	6.5 Hexachl/b. 7.5 Gli sonite			FF4M131S							D /1.1 MOD	CAR,SUS	
24	30 Ti	70 Fe203				FF30MIXV	1.09	N/R	Cr/NR	10 80E	6.5s/in	659		G /1.3 SLIGHT	
25	FF1, 1, II & III,	TNC Pyro.Comp. 1 1:20/15: Si/ZrH2 11:16/15: Si/ZrH2 11:130/20:Si/ZrH2	10TNC 10TNC 1 10TNC 1 Pluronic F68	5 Lam.4116 4 Lam.4116 4 Lam.4116 Gel, Nitrate	FF1,1,II, FF1,1,II, FF1,1,II FF1,1,II	9.76	Cr/NR	26				680	476	D /1.1 MOD	
														CAR,SUS TOXIC CAR,SUS	
26	TNC, FF11 (Slurry)					FFM125A1									
27	TNC, FF1 (Slurry)					FF127A1									
28	TNC, FF11 (Slurry) or 16 BPowder/Cl-B	84 TNC FF11 (Slurry) Pluronic F68	Pluronic F68 Gel,Nitrate MEK			FF158A1 FFM158A1	3.78								
29	TNC, FF1 (Not A Slurry) or 19 B powder 19. Pow.: 19 B 18/58; Ty 1V Te/KH03	39 Ignition Pwd. (Not A Slurry)	5 P.ester			FFM583A1	11.4								
30	20 Si	80 Pb304	1.8 (10 NC 90 Ac+)			FFM201A1	0.82								/1.3 TOXIC
31	10 Si	90 Pb304	1.8 (10 NC 90 Ac+)			FFM1x	0.65								/1.3 TOXIC
32	25 B VAAR is no longer being produced. An old quotation a \$12.00 / 1b. was used for cost		1 VAAR			I-Semix	19.3 0.124								/1.1 MOD.
33	50 Si	20/30 Pb02/Cu0				Igniter	1.67								
34	40 Si	54 KN03	6 Ultion A			IM-6	3.82 > 1								
35	45 Zr	25 Fe203	10 D. Earth	VAAR added	I-AIA	>69	0.0024	CB/NR	24	.065s/mg	550	427		G/1.3 SLIGHT	
36	21 Zr	79 BaCrO4			OP-162	25.6	0.0013	PB/NR	23	1.0s/in	396	418		/1.1 CAR,SUS	
37	19 B	58/181 KN03/TFE			SI-2B2	0.283		SpK/NR	?					NR(5sec)	D/1.1 MOD.
38	23.1 B	70.7 KN03	0.5Puron/1CF68	5.7 Lam4116	Igniter	1.0BM		NR	13						
39	16.5 Mg	80.5 BaO2	2/1CaRes/Gra-		1-527	1.95 1.25		SpS/NR	23						
			phite												
40	15.0 Ty-111 Mg/Gran	65.0 SrO2	7/131 Ty1/Ty11 Ca Resinate		I-548	0.05 BM		SpKs/NR	8						MOD
41	6 Mg (Gr-12) 1-136: 10 Ca Res.	94 SrO2													

**Table 2**  
(cont)

**Table 2 Database for first fire and pyrotechnic compositions**

No.	Fuel (Percent)	Oxidant (Percent)	Additive (Percent)	Blinder	Solvent	Type (Percent): (Percent)	Cost \$/lb	E.Sta.(J) Union/Con (BR)	Fric.P Steel/F PA,(%)	Impact BR *AS Cal./Q	Heat OffRec Auto/DTA Shown	19-Temp Degrees C 67/142	Compat Toxicity ***Ref (DDG)
42	5 B	95 BaCr04				DP-T-10 (See record #32)	7.15	CB/NR	>40	1.95/in	265	553/675	/1.1 CAR.SUS
43	10 B	90 BaCr04				DP-4779	10.1	CB/CB	12	0.75/in	480	615/705	/1.1 CAR.SUS
44	10 B	90 BaCr04		1 UAR (See record #32)		JP-879	9.70	CB/NR	24	1.55/in	463	560	/1.1 CAR.SUS
45	15 B	85 BaCr04				DP-523	13.2	CB/NR	26	1.55/in	502	/645	/1.1 CAR.SUS
46	19 B	81 BaCr04				DP-T-10	15.7	CB/NR	10	2.05/in	276	656	/1.1 CAR.SUS
47	15 B	44/41 BaCr04/Cr203				DelayMix	13.9			4.55/in			CAR.SUS
48	14 B	44/42 BaCr02/Cr203				DelayMix	13.2			6.55/in			CAR.SUS
49	13 B	41/44 BaCr02/Cr203				DelayMix	12.5			8.55/in			CAR.SUS
50	50 W	40/10 BaCr04/KC104				DelayMix	7.27	NR/NR	22 BOE	125/in	233	270	/1.3 CAR.SUS
51	20 W	70/10 BaCr04/KC104				DelayMix	5.68			415/in			CAR.SUS
52	9.70/30ZnNi alloy	60/14 BaCr04/KC104				DP-1415, Ty11	17.9	CB/NR	>40	6.05/in	521	325	/1.3 CAR.CUS TOXIC
53	3.70/30 ZnNi alloy	60/14 BaCr04/KC104				DP-1415, Ty11	16.6	CB/	>40	11s/in	521	325	/1.3 CAR.SUS TOXIC
54	55 Mn	45 PbCr04				DP-D16	1.07			2.2s/in	230		CAR.SUS
55	33 Mn	30/37 BaCr04/PbCr04				DP-D16B	1.99	NR/NR	15. BOE	8.4S/in	256	460	CAR.SUS
56	32.8 Mn	37/30.21BaCr04/PbCr04				DP-D16C		NR/NR	15 BOE	135/in	262		/1.3 CAR.SUS
57	28 Zr	72 Pb02				DelayMix	22.5			<.5s/in			Toxic
58	5/31Zr/Ni	42/22 BaCr04/KC104				DP-T-2	10.5			6.5s/in			CAR.SUS
59	5/17Zr/Ni	70/81 BaCr04/KC104				DP-HP-25	9.71			18 s/in			CAR.SUS
60	32-58 W	32-56 BaCr04 & 10-14 KC104		UAR (See record #32)		Delay P. Avg. w/oB	7.04 11.03	NR/	36			270	MOD
61	53 Zr	21/261 KC104/Mn03				SI-98					1174	372	
62	48.7 Zr	31.3/201 Mn03/Cr203				SI-1113	54.1	0.00018	CB/CB	34	0.8s/in	605	6/1.3 Low
63	40 Zn120 Al	20 KC104/20 KN03				PFP-600	3.82	>50		14		700	6/1.3 MOD
64	60-67 Al	33-40 KC104				PFP-600	5.9	0.37	CB/NR	24		2284	D/1.1
65	22.5/101 Al(F1.)/S	64/3.5; KC104/Sbs2				H-80							

Table 2  
(cont)

Table 2 Database for first fire and pyrotechnic compositions

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The toxicity and compatibility data were collected from the literature and compatibility data were collected from the manufacturer's handbook of the various materials used in the study.

Safe and Hazardous Chemicals, 1981. Cost data was collected from the latest editions of the most current Chemical Marketing Report, published by the Chemical Publishing Company of New York and by direct contact with Propellant and Explosives Manufacturers and Manufacturing Companies.

Table 2  
(cont)

Abbreviations

E. Sta.	= Electrostatic	Pyro	= Pyrotechnic
J	= Joules	Hexachl'b	= Hexachlorobenzene
Fric. P	= Friction	TNC	= tetranitrocarbazole
BR	= Burning rate	PvCl	= Polyvinyl chloride
Ig. Temp	= Ignition temperature	LAM	= Laminac
Compat	= Compatibility	Cel	= Cellulose
Comp	= Composition	Pwd.	= Powder
Uncon	= Unconfined	Ty	= Type
Con	= Confined	Tef	= Teflon
F	= Fiber	P.ester	= Polyester
PA	= Picatinny Arsenal	CaRes	= Calcium resinate
Rec	= Recation	Sps, Spks, Spk	= Sparks
DTA	= Differential thermal analysis	Pb	= Partial burn
Gr	= Group	Propel't	= Propellant
Haz	= Hazard	TFE	= tetraflouoroethylene
BM	= Bureau of Mines	Cl	= Class
Exp	= Explodes	Sp	= Specification
Cra, Cr	= Crackles	El	= Ellipsoidal
NR	= No reaction	Opt	= Optimal
St.	= Stearic		
Snp, Snps	= Snaps		
St.	= Starter		
Mod	= Moderate		
B	= Binder		
BOE	= Bureau of Explosives		
Solu	= Solution		
Nc	= Nitrocellulose		
pts	= parts		
Ace	= Acetone		
Tox	= Toxic		
SI-Mod	= Slight to moderate		
ERL	= Energetics Research Laboratory		
Bk.	= Black		
B.Acetate	= Butyl Acetate		
CD	= Complete detonation		
CAR. SUS	= Carcinogen suspect		
MEK	= Methyl Ethyl Ketone		
CB	= Complete burning		
D.earth	= Diatomaceous Earth		
E. Acetate	= Ethyl acetate		

Table 3  
Candidate first fire compositions

<u>Constituent</u>	<u>Requirements</u>	Nominal weight percent		
		SM-XXV	IM-6	I-548
Silicon	MIL-S-230 Grade II, Class C	25.7	40.0	---
Potassium nitrate	MIL-P-156 Class I	34.6	54.0	---
Charcoal	JAN-C-178 Class D	4.0	---	---
Aluminum powder	MIL-A-512 Type II, Grade C, Class 4	12.8	---	---
Red iron oxide	MIL-I-275 Grade D	21.7	---	---
Nitrocellulose	MIL-N-244 Grade D	1.2	---	---
Viton A	Commerical	---	6.0	---
Strontium peroxide	MIL-S-612 Grade B	---	---	65.0
Calcium resinate	MIL-C-20470 Type II	---	---	7.0
Calcium resinate	MIL-C-20470 Type I	---	---	13.0
Magnesium powder	MIL-M-382 Type III, Granulation 12	---	---	15.0

**Table 4**  
**Static tunnel (ARDEC) data for various illuminant assemblies**

<u>Assembly for</u>	<u>First Fire</u>	<u># Assemblies</u>	<u>Burn Time, sec</u>	<u>Average Candlepower</u>	<u>Average Efficiency candle-gram/sec</u>	<u>Average Color Value</u>
M125A1 Green Star	FF-III	10	5.1 $\pm$ 0.3	5516 $\pm$ 1040	2347 $\pm$ 430	0.42 $\pm$ 0.02
Cluster Ground	IM-6	10	5.6 $\pm$ 0.5	4196 $\pm$ 1165	1924 $\pm$ 471	0.41 $\pm$ 0.01
Illumination Signal	SM-XXV	10	5.4 $\pm$ 0.5	5962 $\pm$ 991	2677 $\pm$ 282	0.41 $\pm$ 0.00
M158 Red Star	FF-II	10	4.2 $\pm$ 0.4	19349 $\pm$ 3696	6811 $\pm$ 1257	0.54 $\pm$ 0.01
Cluster Ground	IM-6	10	4.8 $\pm$ 0.4	21177 $\pm$ 2897	8511 $\pm$ 1533	0.54 $\pm$ 0.01
Illumination Signal	SM-XXV	10	4.6 $\pm$ 0.5	20323 $\pm$ 1193	7717 $\pm$ 717	0.53 $\pm$ 0.00
M127A1 White Star	FF-I	10	37.9 $\pm$ 1.5	76788 $\pm$ 4367	34302 $\pm$ 2084	0.05 $\pm$ 0.00
Parachute Ground	IM-6	10	39.0 $\pm$ 1.2	56962 $\pm$ 1734	26275 $\pm$ 8204	0.04 $\pm$ 0.00
Illumination Signal	SM-XXV	10	38.6 $\pm$ 0.8	80780 $\pm$ 5359	36784 $\pm$ 2806	0.05 $\pm$ 0.00
M583A1 White Star	FF-I	10	26.0 $\pm$ 2.9	110631 $\pm$ 4513	36827 $\pm$ 3874	N. A.
40mm Parachute	IM-6	10	21.0 $\pm$ 4.6	112867 $\pm$ 16744	32251 $\pm$ 3358	N. A.
Cartridge	SM-XXV	10	23.2 $\pm$ 2.4	106327 $\pm$ 11498	32369 $\pm$ 2655	N. A.

Table 5  
Static tunnel (LHAAP) data for standard and candidate illuminant assemblies

<u>Assembly</u>	<u>First fire</u>	<u>No. assemblies</u>	<u>Average burn time, sec</u>	<u>Average candlepower</u>
M127A1	FF-I	20	$34.0 \pm 0.8$	$114,100 \pm 5,890$
M127A1	SM-XXV	20	$31.0 \pm 0.9$	$135,100 \pm 9,010$

**Table 6**  
**Ballistic data for signals conditioned at -65°F**

	M127 with FF-I	M127 with SM-XXV	Requirements
# Fired	16	16	16
# Functioned	16	16	16
Average	$715 \pm 38$	$700 \pm 76$	None
Altitude, feet			
Maximum	805	784	None
Minimum	652	433	None
Average	$6.0 \pm 3.2$	$11.0 \pm 9.1$	$\leq 25$
Angle, degrees			
Maximum	14	44	None
Minimum	2	3	None
Average	$0.82 \pm 0.08$	$0.82 \pm 0.15$	None
Chute Delay, seconds			
Maximum	0.92	1.29	5
Minimum	0.66	0.63	None
Average	$37.0 \pm 1.3$	$37.0 \pm 1.2$	None
Burn Time, seconds			
Maximum	39.1	38.7	None
Minimum	34.1	35.1	25

Table 7  
Ballistic data for signals conditioned at 70°F

	MM127 with FF-I	MM127 with SM-XXV	Requirements
# Fired	32	32	32
# Functioned	32	30	32
Average	815 $\pm$ 34	821 $\pm$ 42	>725
Altitude, feet			
Maximum	889	916	None
Minimum	719	743	500
Average	4.0 $\pm$ 2.4	4.0 $\pm$ 2.4	$\leq$ 12
Angle, degrees			
Maximum	10	9	30
Minimum	1	1	None
Average	0.72 $\pm$ 0.06	0.74 $\pm$ 0.09	None
Chute Delay, seconds			
Maximum	0.91	0.95	5
Minimum	0.64	0.59	None
Average	32.9 $\pm$ 1.2	32.5 $\pm$ 0.8	None
Burn Time, seconds			
Maximum	34.7	34.9	None
Minimum	30.6	30.5	25

**Table 8**  
Ballistic data for signals conditioned at 165°F

		MM127 with FF-1	MM127 with SM-XXX	Requirements
# Fired	32	32	32	32
# Functioned	32	32	32	32
Average	828±34	845±25		None
Altitude, feet				
Maximum	886	916		None
Minimum	684	803		None
Angle, degrees				
Average	4.0±2.5	4.0±2.4		None
Maximum	10	8		None
Minimum	1	0		None
Chute Delay, seconds				
Average	0.67±0.08	0.69±0.10		None
Maximum	0.83	1.06		None
Minimum	0.53	0.56		None
Burn Time, seconds				
Average	31.2±1.3	30.6±1.3		None
Maximum	35.1	33.8		None
Minimum	28.8	28.4		None

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